The Mark Ortiz Automotive

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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortizauto@windstream.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

WHEN LOTS OF FRONT ROLL STIFFNESS HELPS, AND WHEN IT DOESN'T

The following question was forwarded to me by a correspondent who said they got it from a Formula Student/Formula SAE forum, where somebody was suggesting it should be put to me.

In the UK most of the successful hillclimb and sprint cars have a monoshock front suspension which is very stiff in roll. Examples include the Gould and Force cars, and more recently Graeme Wight Jr's Raptor design. The rear suspension is often considerably softer in both bounce and in roll. As a consequence the cars often corner on three wheels, with the inside front lifting. Why is this a successful method when all of the suspension/chassis technical books suggest that weight transfer results in a loss in overall grip due to the non-linearity of the tyre?"

We have debated this topic in the amateur paddock and have come to the conclusion is that these technical sources are generally correct for tyres which are already up to temperature. However in a hillclimb or sprint the tyres are initially cold, so the grip gained by tyre temperature increase may outweigh the loss in grip through loading up the outside tyre.

Furthermore the hillclimb tracks are often very heavily cambered so cornering on 3 wheels may improve car stability and tyre contact patch. My analogy would be the stability of a table on any uneven floor; stability can be achieved by 3 good points of contact.

I have added A/R bars to my OMS in order to stiffen the car in roll, particularly at the front. My OMS 1100 has conventional independent suspension all round with Koni double adjust dampers. Attached is a photo at an Aintree sprint showing the inside front just lifting. The car feels better with the A/R bars and takes sweeping corners better than before. I am convinced that I can lean on the car much more now in corners.

First of all, it is vital to recognize that having a lot of front roll resistance, relative to the rear, does not increase overall load transfer. It increases front load transfer, and decreases rear load transfer, and the total remains essentially unchanged.

Increasing overall roll resistance does not increase load transfer either. It just reduces roll, and, accordingly, camber change. It is true that stiffer settings tend to heat tires faster, and more, because the tires experience more dramatic load changes as they go over bumps.

Whether more heat helps the tire depends on the compound. In general, tires intended for long runs are designed to heat up and get tacky. Tires intended for short events such as sprints, hillclimbs, or autocross often use compounds that are tacky at room temperature. The Hoosier tires used by Formula SAE teams I have worked with use the same A25 compound for the slicks and for the moulded rain treads: the dry tires use a rain compound, and consequently work well when moderately cold. They do get hot as they run, but they don't benefit much from it.

It probably makes good sense to use heat-insensitive compounds for short events, if for no other reason than to give the driver a car that doesn't change dramatically in the course of a run.

Whether they are heat-sensitive or not, tires generally do follow accepted theory as regards load sensitivity of the coefficient of friction, cold or hot: the coefficient of friction does decrease as normal force increases; a pair of tires make less force the more unequally they are loaded.

Consequently, a setup with more front roll resistance, relative to rear, will be tighter (have more understeer). This tends to be a good thing in sweepers, and a bad thing in tight turns. Not only do most drivers prefer a looser (more oversteering) car in tighter turns, but cars tend to get tighter as turn radius decreases, especially at really small radii, as seen in FS/FSAE events.

This is partly due to "off-tracking": the rear tires track inside of the front ones in a tight turn, even when running at a significant slip angle, and track outside of the fronts in a large-radius turn when running at a slip angle. Even at steady speed, as on a skidpad, the driver must apply substantial power in limit cornering, just to overcome tire drag. Assuming rear drive, when the rear tires are tracking inside of the fronts, the drag force from the front tires creates a pro-understeer (outward to the turn) yaw moment, and so does the propulsion thrust from the rear tires. When the rear tires track outside the fronts, the effect reverses, and the yaw moments from drag and thrust add oversteer.

Again assuming rear drive, a car also tends to get looser in conditions requiring heavier throttle application: corner exit; hill climbing; high speed turns. This results from the "traction circle" effect: the tires can't make as much lateral force when they are being asked to make longitudinal force.

Uphill, this effect is partially countered by rearward load transfer resulting from gravity, but generally a powerful car will be looser uphill than on level ground. This explains why, in the old days, people put dual rear tires on hillclimb cars.

Finally, if the car has any form of limited-slip differential, or a spool, there is a "locked axle push" effect when cornering, and this becomes more pronounced in smaller-radius turns.

This explains why autocross cars, and especially FS/FSAE cars, don't want a front-stiff setup, while hillclimb cars do, and cars for full-size road courses generally fall somewhere in between, depending on aero properties. FSAE events are run in parking lots. There is little climbing or descending involved. There are no sweepers. The courses are designed to keep speeds very low, in the interest of safety.

The last FSAE car I drove has roughly 57% static rear weight, give or take about 1% depending on driver weight. It has equal size tires front and rear. Ordinarily, one would expect a car like that to have some oversteer even if it were set up to lift a front wheel. But on the turn radii used in FSAE, that doesn't happen. The car has to be set up so rear-stiff that inside rear wheelspin is a problem. When you are cornering near the lateral force limit, you can't throttle-steer; the inside rear spins, and the outside rear stays stuck. That's with a Gleason-style limited-slip. The inside rear can't transmit enough torque to lock the Gleason. Earlier cars, with less rear percentage, would lift the inside rear off the ground on the skidpad.

Any attempt to get more inside rear loading resulted in excessive understeer.

The cars also use considerable static negative camber at the front, and considerable caster, so that the front wheels corner at more favorable camber than the rears, or at least the outside front does.

Typical skidpad sizes for testing full-size cars are 200 or 300 feet diameter. FSAE skidpads are 50 feet in diameter at the inside. A good car can pull around 1.3g lateral acceleration. The car is at its steady-state lateral force limit, at a speed of about 25mph.

These cars should be loose in a sweeper. I can't tell you from experience whether they are. We have never run an FSAE car anyplace where there was a sweeper.

Finally, we should note that this whole discussion applies to rear-drive cars, and that when we speak of greater or lesser front-stiff roll resistance distribution, we are speaking in relative terms. A given design will need a more rear-stiff setup when used for autocross than when used for hillclimbing or full-size road course work, but that does not necessarily mean that all autocross cars are more rear-stiff than all hillclimb cars, irrespective of all other factors.